5

Ultimately, construction of new transmission facilities will be needed to ease transmission bottlenecks. We must implement open, regional transmission planning processes that consider a broad range of transmission and non-transmission alternatives, accelerate and coordinate siting and permitting processes for needed facilities, ensure that the transmission system can take advantage of the latest technologies, and address physical and cyber security issues.

Relieving Transmission Bottlenecks Through Effective Investments

Improving transmission system operations will go a long way toward easing transmission bottlenecks by delaying or alleviating the need for construction of new transmission facilities. However, construction of new facilities cannot be avoided entirely. We must ensure that needed facilities are identified in a timely fashion through open processes and that, once identified, they are constructed expeditiously.

In view of its ongoing responsibilities for public-interest energy R&D, DOE must work closely with industry to ensure the continued development and deployment of needed new, transmission-enhancing technologies. This need is especially great today to address gaps that have emerged during the transition to competitive regional wholesale markets. Finally, we must also re-double efforts to ensure the security of new and existing facilities in the nation's transmission infrastructure.

5

Implementing Regional Transmission Planning

Effective regional transmission planning requires:

- An open, inclusive process;
- Clear planning objectives; and
- A planning entity with authority to conduct the process and implement the results.[39]

FERC Order 2000 assigns responsibility for transmission planning to RTOs. Vesting this responsibility in RTOs is an acknowledgment of the regional implications of transmission in facilitating the development of regional wholesale electricity markets. RTOs are the key institutions with a regional perspective central to

[39]For additional background on this discussion, see the Issue Paper, "Transmission Planning and the Need for New Capacity," by E. Hirst and B. Kirby.

their charter. As noted in Section 3, DOE believes that a key element of RTOs' role in transmission planning should be to identify and address transmission bottlenecks

It is critical that the RTOs formed in response to FERC Order 2000 adopt planning principles and practices that facilitate private investment in new transmission facilities and non-transmission alternatives. These principles and practices should advance local, state, regional, and national interests. The goal of RTO planning should be to identify transmission needs and the criteria for evaluating proposed solutions, and then to empower the market to respond to these needs, including, if necessary, support for market solutions in state regulatory proceedings.

A critical challenge is to reintegrate the generation and transmission system planning perspectives that were once a routine element of planning by vertically integrated utilities. Today, generators are building power plants where permits can be obtained with ease and there is access to fuel, water, and other necessary infrastructure. Transmission issues are an afterthought in this process because transmission is viewed as the utilities' obligation. For example, in the Southeast, a large number of power plants have been proposed in areas where there is inadequate transmission. Building new generation in these areas will increase congestion on the transmission system.

Expansion of the transmission system must be viewed as one strategy in a portfolio to address transmission bottlenecks; this portfolio also includes locating generation closer to loads, relying on voluntary customer load reductions, and targeting energy efficiency and distributed generation. Planned natural gas infrastructure investments, which affect where new generation will be built (both large, remote stations as well as small, distributed generation), must also be considered.

Once transmission bottlenecks are identified, market-based approaches should be relied upon to address them in the most efficient way. As mentioned in the previous section, one way to empower market solutions is better pricing of transmission congestion to signal needs to private developers so that they can capture the benefits of relieving transmission bottlenecks. Better pricing allows generators to incorporate transmission considerations into their business decisions for locating new power plants.

When possible, solutions to bottlenecks should be solicited through open, competitive processes that allow private developers to offer proposals that might encompass new transmission facilities, non-transmission alternatives, or both. Access to operational data is essential to allow market participants to formulate and evaluate viable proposals.

Transmission plans must balance traditional reliability considerations with economic efficiency. Taking the economic efficiency attributes of electricity markets into account requires adopting a regional perspective because these markets span across regions. This is in sharp contrast to most current transmission plans, which, because of the limited geographic scope and mandate of today's transmission owners, focus primarily or solely on local considerations.

In contrast to the majority of today's transmission planning processes, open planning processes will be essential to ensure meaningful public input throughout. This input is especially needed to support the identification and assessment of tradeoffs among planning criteria (e.g., reliability versus economic efficiency, local impacts versus regional benefits) as well as to better understand how parties might be affected by different planning outcomes. Too often, clear planning criteria and public input are delayed until state and federal siting processes are under way. Delaying public input until the siting process can cause substantial delays because it often introduces new alternatives that had not previously been evaluated. The siting process must then be stopped while these new possibilities are assessed. These delays can be avoided if planning criteria and public input are incorporated early in the planning process. Greater public access to planning data and resources is needed to effectively inform public input.

Meaningful public input and assessment of reasonable alternatives in the early stages of planning will increase public acceptance of plans once they are final and will facilitate any required siting and permitting processes.

RECOMMENDATION

- DOE will work with the electricity industry and state and federal regulators to identify the type of electricity system data that should be made available in the planning process to facilitate the development of market-based transmission solutions and devise a process for making that information available.

5

Accelerating the Siting and Permitting of Needed Transmission Facilities

There have been significant delays during the siting and permitting process for many large, interstate or regional transmission projects.[40] These processes have emerged as significant deterrents to building new regional transmission facilities. It is important that we eliminate unnecessary delays once the need for these facilities has been established.

State and federal regulators must work with states and regions to ensure that transmission siting and permitting processes work —and work together. States should retain their present authority and play a more active role in managing review processes for energy infrastructure siting and permitting. As part of their reviews, states should ensure that regional considerations are taken into account in assessing the costs and benefits of new transmission. They should also coordinate their reviews with other regional and state planning, siting, and permitting processes. As part of these processes, the federal government has a special responsibility to ensure that siting and permitting on federal lands is not needlessly delayed.

Federal regulators should actively support and defer to these state and regional siting and permitting processes. However, since new regional transmission facilities will typically span or impact multi-state areas that seldom align with the political boundaries of states, FERC must have appropriate backstop authority to ensure that the public interest is served and that national interest transmission bottlenecks designated by DOE are addressed. When state and regional processes determine that construction of transmission facilities is needed to address national interest transmission bottlenecks, yet are unable to site or permit them in a timely fashion, FERC must be able to grant designated entities the right of eminent domain to acquire property for rights-of-way.

[40]For additional background on this discussion, see the Issue Paper, "Transmission Siting and Permitting," by D. Meyer and R. Sedano.

American Electric Power's 765-kV Project between West Virginia and Virginia

Ten years after it was first proposed, a major transmission project by American Electric Power (AEP) in West Virginia and Virginia is still about a year from final approval. The following chronology documents the delays resulting from state regulators' efforts to take account of local and other concerns, and from lack of coordination among the principal parties.

1991—AEP submits a proposal for a 765-kV transmission line to Virginia, West Virginia, the U.S. Forest Service, the National Park Service, and the U.S. Army Corps of Engineers with the goals of maintaining reliability in southern West Virginia and southwestern Virginia and reducing the risks of a cascading outage that could affect many states in the eastern U.S.

1992–1994—Extensive hearings are held in Virginia and West Virginia, many in potentially affected localities.

1996—The Forest Service issues a draft environmental impact statement which recommends that the line not be constructed as proposed because it will cross sensitive public lands.

1997—AEP proposes, to the regulatory commissions in the two states, a longer alternate route that would cross less sensitive areas than the initial route.

1998—The West Virginia Public Service Commission approves its portion of the alternate route.

Later in 1998—AEP agrees to a request from the Virginia Corporation Commission that the utility conduct a detailed study of a second alternate route. After AEP completes its review, it agrees that the second route is acceptable although this route would not allow as much margin for future load growth as had been available with the first alternate route.

2001—The Virginia Corporation Commission approves the second route, chiefly because this route would have fewer adverse environmental and social impacts than the previous routes.

Late 2001—The West Virginia Public Service Commission must review and approve the newest route even though the West Virginia portion of that route differs very little from the one the commission approved in June 1998. In addition, because the newest route would also cross about 11 miles of national forest in an area not studied in the Forest Service's 1996 draft environmental impact statement, the Forest Service must conduct a supplementary analysis before deciding whether to grant a permit for construction.

Source: D. Meyer and R. Sedano. 2002. *Transmission Siting and Permitting.* Issue Papers.

The Alturas Line

Sierra Pacific's experience in building a 163-mile transmission line is an example of the costs and delays that can arise when transmission projects involve multiple federal agencies with land management responsibilities.

Sierra Pacific prepared detailed plans for the Alturas project in 1992. The Nevada Public Service Commission approved the project in November 1993. After obtaining Nevada's approval, Sierra Pacific turned to the other affected agencies—the California Public Utilities Commission (CPUC) and several Federal agencies: the U.S. Bureau of Land Management (BLM), the U.S. Forest Service, BPA, and the U.S. Fish and Wildlife Service. BLM had the most acreage affected by the proposal and became the lead agency for the Federal review of the project. CPUC became the lead agency for state environmental purposes. In spring 1994, BLM and CPUC collaborated to begin a draft environmental impact report (EIR) for the state and a draft environmental impact statement (EIS) for the Federal agencies. Sierra Pacific paid the cost of the studies. BLM issued the final EIS in November 1995 and approved its portion of the project in February 1996. The CPUC approved its portion of the line in January of 1996.

In February 1996, the manager of the Toiyabe National Forest issued a "no action" decision, arguing that the EIS was flawed because it had not addressed a sufficiently wide range of alternatives. Eventually, Sierra Pacific decided to pursue an alternative route and withdrew the application to cross the Toiyabe area. In April 1997, the Modoc National Forest manager denied the project a permit to cross a three-mile portion of the Modoc National Forest. The applicant appealed this decision to the chief of the Forest Service in May 1997; a permit was issued October 1997. However, several other parties to the proceeding appealed this permit. After review, the decision to issue the permit was upheld in January 1998.

Construction was begun in February 1998 and completed in December 1998. Sierra Pacific estimates that the project was delayed by at least two years and that these delays led to additional costs of more than $20 million.

A Coordinated Regional Approach

One way to reduce delays in siting and permitting is to foster coordinated review when several state or federal agencies are affected by a proposed facility. When proposed facilities cross boundaries between states or cross lands managed by one or more federal land management agencies—which is frequently the case for facilities whose impacts are regional in nature—the potential for miscommunication, poor coordination, and delay is increased significantly. As demonstrated by the AEP example (see text box), failure by state and federal agencies to coordinate their reviews can lead to the issuance of permits that are inconsistent with one another. This can necessitate multiple additional rounds of review to resolve differences and further delay an already lengthy process. A common timetable and coordinated process for affected agencies is needed to reduce these delays.

Transmission systems are regional in scope, and their benefits are generally regional in nature, yet frequently their impacts are local. Siting processes need to take a regional perspective, incorporating local input to fairly and equitably assess a wide range of proposals for transmission enhancements. Regional coordination for siting and permitting should be organized according to RTO boundaries.

State and federal siting agencies can improve regional siting and permitting by working together in a cooperative fashion to:

- Agree on the information that is necessary to evaluate a transmission proposal;
- Develop common documents (e.g., environmental impact statements) for reviewing proposals;
- Set a reasonable time frame for completing review and issuing required permits; and
- Ensure that the completed permits are consistent.

A coordinated regional approach is being developed by the Western Governors' Association, which has formed the Committee for Regional Electric Power Cooperation (CREPC) to address regional transmission planning and siting issues in the Western Interconnection. Similar efforts for regional coordination in planning and siting transmission should be undertaken within the Eastern Interconnection.

DOE encourages development of regional protocols to govern the siting of transmission facilities. These protocols should ensure that states within a region follow the same rules and that the rules are enforced. Regional transmission siting protocols should include:

- Agreements that states concurrently review proposals;
- Ground rules for addressing reliability issues;
- A provision for common assessment of market power in the region;

Regional Transmission Planning and Development of Cooperative Regional Institutions

A promising example of a regional institution that could be used to address regional transmission siting issues on a cooperative basis is the Western States' Committee for Regional Electric Power Cooperation (CREPC). CREPC was created jointly in 1984 by the Western Interstate Energy Board, which acts as the energy arm of the Western Governors' Association, and the Western Conference of Public Service Commissioners. CREPC has representatives from the regulatory commissions and energy and facility-siting agencies in the 11 states and two Canadian provinces in the Western Interconnection. Through CREPC, the western states have begun negotiations to develop a common interstate transmission siting protocol; June 2002 is the target date for publication of their draft.

Source: Western Interstate Energy Board. http://www.westgov.org/wieb/crepnew2.htm

- A provision for consideration of the ways that a proposed transmission facility might increase regional fuel diversity;
- Criteria for evaluating both transmission and non-transmission alternatives; and
- Requirements for disclosure of existing rights of way and opportunities to increase the transmission capacity of existing facilities.

Responsibilities of Federal Agencies

The record for siting transmission lines across federal lands is spotty. Some efforts to build lines across federal lands, especially in the Western U.S., have been delayed or stopped by an inconsistent and time-consuming process. DOE believes that federal agencies that manage federal lands and natural resources should support regional transmission siting agreements. These agreements should provide for cooperation, timely participation, dedication of sufficient resources to carry out required

Distribution of Federal Lands in the United States

Although almost 29 percent of the land area of the United States is federally owned, 54 percent of federally owned land is concentrated in the 11 states of the contiguous U.S. located wholly or partially west of the Continental Divide.

State	Total Area in Acres	% Federal Land
Arizona	72,688	45.6
California	100,207	44.9
Colorado	66,486	36.4
Idaho	52,933	62.5
Montana	93,271	28.0
New Mexico	77,766	34.2
Nevada	70,264	83.1
Oregon	61,599	52.6
Utah	52,697	64.5
Washington	42,694	28.5
Wyoming	62,343	49.9

Source: *Statistical Abstract of the United States, 2000* (U.S. Dept. of Commerce, December, 2000), Table No. 381 (1997 data).

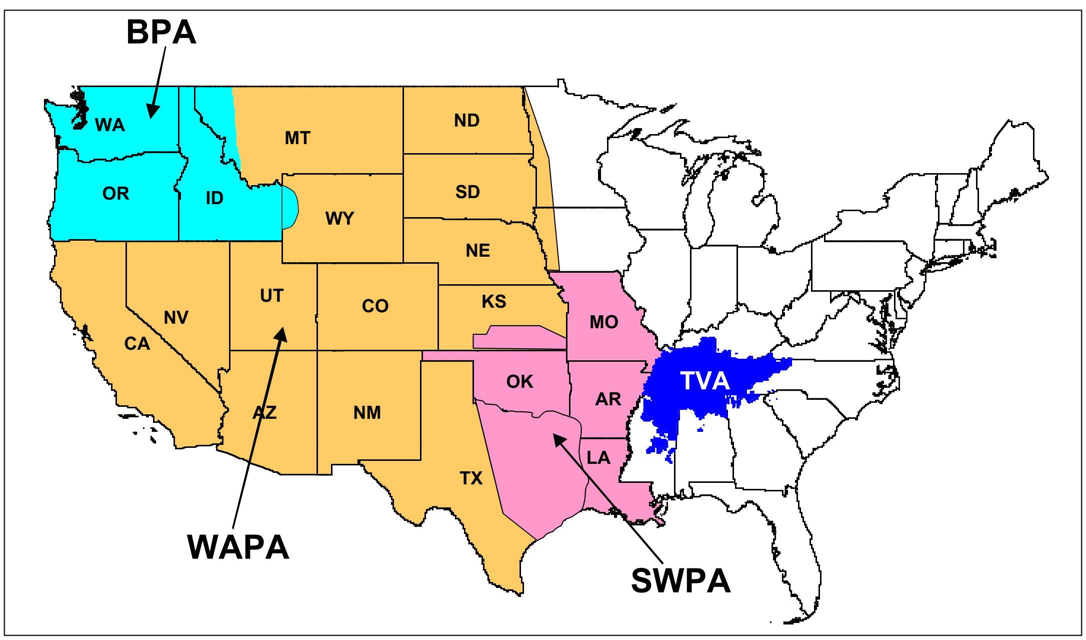


Fig. 5.1
WAPA, BPA, SWPA, and TVA Power Marketing Areas

environmental reviews, and integration of review requirements by all parties for proposed transmission lines. These agreements should ensure that National Environmental Policy Act and other reviews are conducted in a coordinated and timely manner. As shown in the chart on the previous page, the federal government still manages large sections of land in the United States.

The present administration has worked to improve coordination among federal agencies. To help address transmission bottlenecks, the federal government should continue to improve coordination among federal agencies. A key first step should be a jointly developed process for expedited evaluation of permits for construction or modification of transmission on federal lands.

Federal agencies should support regional planning efforts by identifying and evaluating potential transmission corridors across federal lands. In addition, federal agencies should reexamine existing transmission paths across federal lands to determine the potential to increase transmission capacity along these paths.

Establishing a FERC Role in Transmission Siting

Electricity transmission is a vested public interest. As the U.S.'s demand for electricity grows and new generation capacity is built to meet this demand, the need for more transmission capacity will follow. Increasing transmission capacity will include the construction of longer, higher voltage lines. These lines will allow delivery of the least expensive electricity that is being produced at the time, possibly several states away, to consumers.

Construction of transmission facilities that are needed to significantly advance national interests must not be delayed. Rules and regulations that will improve

procedures for the siting and permitting of transmission lines should be implemented immediately. The FERC should play a limited role focused on supporting state and regional efforts, but should also possess backstop authority to ensure that transmission facilities that eliminate national interest transmission bottlenecks are sited and constructed. The FERC should act if state and regional bodies are unsuccessful in siting and permitting national interest transmission lines. In order to serve the public interest, the FERC should enable an applicant to exercise the right of eminent domain to acquire property to site and permit transmission facilities in these instances. Eminent domain is used by many different branches of the federal government to acquire property to serve the public interest.

- The Federal Aviation Administration uses eminent domain to acquire land for radar installations.
- The General Services Administration has used eminent domain to acquire property rights to provide security and has used eminent domain to acquire office space when other negotiations have failed.
- The four Department of Energy strategic petroleum reserve sites in Louisiana and Texas were established by eminent domain.
- The FERC may grant a certificate of public convenience and necessity to a natural-gas company which gives the recipient the right to exercise eminent domain to acquire property for rights-of-way in the siting and construction of natural gas pipeline facilities.
- Power Marketing Administrations use

eminent domain to site transmission facilities in much of Midwest and Western United States

DOE believes that Congress should grant limited federal siting authority to FERC to be conveyed only when a transmission facility that would significantly advance national interests is in jeopardy of not being built and only after regional bodies have determined that this facility is preferred among all possible alternatives.

RECOMMENDATIONS

- FERC and DOE should work with states, pertinent federal agencies, and Native American tribes to form cooperative regional transmission siting forums to develop regional siting protocols.
- Utilities and state utility commissions should develop an inventory of underutilized rights of way and space on existing transmission towers. DOE will work with PMAs and TVA to conduct a comparable evaluation.
- DOE will work with NGA, regional governors' associations, NARUC, and other appropriate state-based organizations to develop a list of "best practices" for transmission siting.
- DOE will undertake demonstration programs to support the use of innovative approaches to transmission planning and siting (e.g., reliance on open planning processes, consideration of a wide range of alternatives, incorporation of innovative or uncommonly employed technologies, use of alternative mitigation measures, etc.).
- Federal agencies should be required to participate in regional siting forums and meet these forums' deadlines for reviews or complete reviews within 18 months, whichever occurs first.
- All federal agencies with land management responsibilities or responsibilities for oversight of non-federal lands should assist FERC-approved RTOs in the development of transmission plans.
- Congress should grant FERC limited federal siting authority that could only be used when national-interest transmission bottlenecks are in jeopardy of not being addressed and where regional bodies have determined that a transmission facility is preferred among all possible alternatives.
- The Council on Environmental Quality should continue to coordinate efforts with the Secretary of the Interior, Secretary of Energy, Secretary of Agriculture, Secretary of Defense, and Administrator of the EPA to ensure that federal permits to construct or modify facilities on federal lands are acted upon according to timelines agreed to in any FERC-approved regional protocol. The agencies should work together to re-evaluate the development of transmission corridors across federal lands and identify the current and potential future use of existing transmission corridors on federal lands.

5

Ensuring the Timely Introduction of Advanced Technologies

The electricity system is one of the greatest engineering achievements of the 20th century. The system has benefited from countless technological innovations that have lowered costs and increased reliability. Today, many more innovations are not being utilized because their pathway to the market is blocked by the business uncertainties resulting from the incomplete transition to a fully restructured electricity industry. A large number of advanced transmission technologies are available that could enhance reliability and dramatically increase electricity flows through existing transmission corridors (Table 5.1).[41]

Table 5.1

Advanced Transmission Technologies

Technology	Overview	Commercial Status
High-Temperature Superconducting Cables	Superconducting ceramic cables can carry much more current than standard wires of the same size, with extremely low resistance, allowing more power to flow in existing right-of-ways. But the required refrigeration results in higher initial and ongoing costs.	Demonstration project underway with cables up to 400 ft. Self-contained current limiters are close to commercial availability.
Underground Cables	Underground cables transmit power with very low electromagnetic fields in areas where overhead lines are impractical or unpopular. Costs are 5 to 10 times that of overhead lines, and electrical characteristics limit AC lines to about 25 miles.	Widely used when overhead is not practical, mostly in urban areas and underwater. Research is ongoing to reduce costs.
Advanced Composite Conductors	New transmission conductors with composite cores, as opposed to steel cores, are both lighter and have greater current carrying capacity, allowing more power to flow in existing right-of-ways.	Just entering commercial testing. More experience is needed to lower total life cycle costs.
More Compact Transmission Line Configurations	New computer-optimized transmission line tower designs allow for more power to flow in existing right-of-ways.	Commercially available, with increasing use.
Six or Twelve Phase Transmission Line Configurations	Practically all AC high voltage power transmission is performed using three phases. The use of six or even twelve phases allows for greater power transfer in a particular right-of-way with reduced electromagnetic fields due to greater phase cancellation.	Demonstration lines have been built. Key challenge is cost and complexity of integrating with existing three phase systems.
Modular Equipment	Modular equipment designs provide greater transmission system flexibility, allowing the grid to quickly adapt to changing usage. They could also facilitate emergency deployment from a "strategic reserve" of critical devices, such as transformers.	Many standards already exist, but further work is needed.
Wireless Power Transmission	High power, wireless transmission using either microwave or laser radiation is being explored. Application includes power transmission from earth to orbiting satellites.	Not expected to be competitive for at least 20 years except in very specialized niche markets such as space power.

Continued on next page

[41]For additional background on this discussion, see the Issue Paper, "Advanced Transmission Technologies," by J. Hauer, T. Overbye, J. Dagle, and S. Widergren.

Advanced Transmission Technologies (continued)

Technology	Overview	Commercial Status
Ultra High Voltage Lines	Higher voltage lines can carry more power than lower voltage lines. The highest transmission voltage line in North America is 765 kV. Higher voltages are possible, but require much larger right-of-ways, increase need for reactive power reserves, and generate stronger electromagnetic fields.	Voltage levels of 1000 kV are currently used in Japan. Electromagnetic fields, right-of-way, and technical concerns limit use in the U.S.
High-Voltage DC (HVDC)	HVDC provides an economic and controllable alternative to AC for long distance power transmission. DC can also be used to link asynchronous systems and for long distance transmission under ground/water. Conversion costs from AC to DC and then back to AC have limited usage. Currently there are several thousand miles of HVDC in North America.	Converter costs are decreasing making DC an increasingly attractive alternative. Most merchant transmission lines propose utilizing HVDC.
Flexible AC Transmission System (FACTS) devices	FACTS devices use power electronics to improve power system control, helping to increase power transfer levels without new transmission lines. But currently they are expensive, making FACTS uneconomic for most transmission owners.	Several large demonstrations projects are operating. New power electronics advances may result in costs reductions.
Energy Storage Devices	Energy storage devices permit use of lower cost, off-peak energy during higher-cost peak-consumption periods. Some specialized energy storage devices can be used to improve power system control. Technologies include pumped hydro, compressed air, superconducting magnetic energy storage (SMES), flywheels, and batteries.	Demonstrations are underway for many advanced storage technologies. The economics of the others is still elusive except in small markets.
Controllable Load	Fast-acting load control has the potential to become an important part of transmission system control. Flexible load allows higher normal-power transfer levels since during system emergencies the load can be rapidly curtailed.	Commercially available with increasing use.
Distributed Generation	Small, distributed generators, including conventional (e.g., diesel generators) and newer (e.g., PV, fuel cells and microturbines) technologies, allow generation to be located close to the load, decreasing the need for reliance on the transmission system.	Commercially available with the economics dependent upon the price of natural gas and utility interconnection policies. Ongoing maintenance costs are also an issue.
Enhanced Power Device Monitoring	The operation of many power system devices, such as transmission lines, cables, and transformers is limited by the device's thermal characteristics. The high operating voltages of these devices make direct temperature measurement difficult. Lack of direct measurements required conservative operation, resulting in less power transmission capacity. Newer dynamic sensors have the potential to increase transmission system capacity.	Commercial units are available to measure conductor sag allowing for dynamic transmission line limits. Dynamic transformer and cable measurement units are also commercially available.
Direct System State Sensors	In some situations the capability of the transmission system is limited by region-wide dynamic constraints. Direct system voltage and flow sensors can be used to rapidly measure the system operating conditions, allowing for enhanced system control.	High speed power system measurement units are commercially available and are being used by several utilities. Research has only begun to examine use of these measurements for real time control of the power system.

Source: J. Hauer, T. Overbye, J. Dagle, and S. Widergren. 2002. *Advanced Transmission Technologies.* Issue Papers.

One class of technologies that could be used seeks to improve throughput of electricity over existing transmission corridors by using advanced composite materials for new overhead conductors and high-temperature superconducting (HTS) cables that can carry five times as much electricity as copper wires of the same size. DOE has been a leader in developing HTS (see text box). Another approach to better utilization of existing corridors is improvement in the configuration of transmission lines or placement of conductors underground, which also minimizes some environmental impacts of electricity transmission.

High-Temperature Superconductivity

At the beginning of 2002, the Southwire Company, in a 50/50 cost share with DOE, completed two years of the first operational test of superconducting cables in an industrial application.

During the past decade, DOE and industry have pursued research on a promising technology called high-temperature superconductivity. Superconductivity refers to a physical state of materials at which electricity can pass with no loss of energy. Formerly thought to occur only at very low temperatures, which would not be practical in commercial applications, superconductivity has been de-monstrated with newer materials at higher temperatures. Commercial applications of superconductivity that are now being explored include more efficient motors, generators, transformers, and other electric equipment.

For electricity transmission, superconductivity offers the promise of dramatically lowering the losses associated with long distance transmission of electricity. Electricity losses in transmission and distribution systems exceed 10 percent of total electricity generated. Reducing these losses would represent hundred of millions of dollars in annual savings to the nation's electricity bill.

DOE supports industry efforts to commercialize superconducting technologies through basic research and testing that will speed its acceptance and use. In partnership with industry, DOE expects to assist industry in rapidly moving these technologies into the marketplace.

Several states, including Michigan, New York, and Ohio, will soon see first-of-a-kind operational testing of superconducting generators, power lines, and transformers. These real-world experiences will lay the foundation for widespread use across the grid of this next-generation technology that provides higher capacity, greater reliability, and improved efficiency.

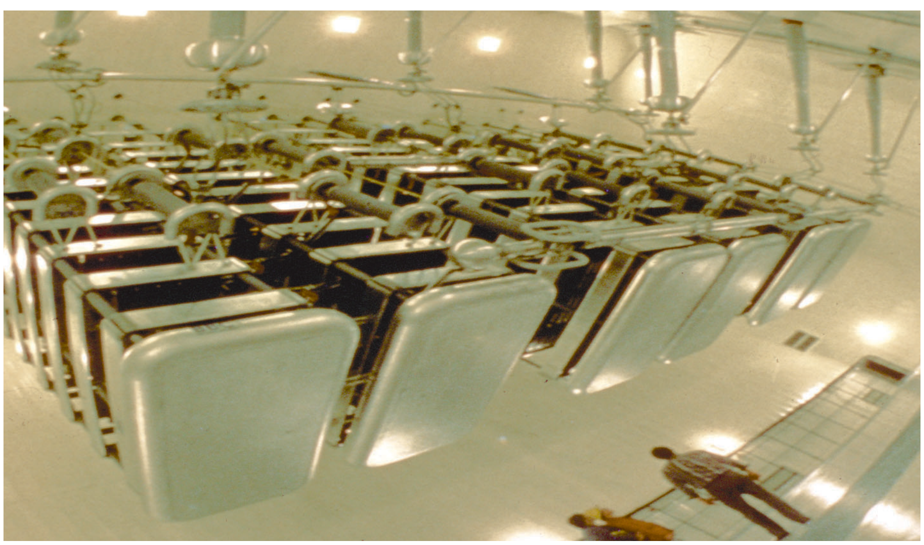
Source: U.S. Department of Energy. http://www.eren.doe.gov/superconductivity/

Another class of technologies enables better control of the flow of electricity over existing lines. Flexible AC transmission system (FACTS) devices are high-voltage power electronics devices that allow precise and rapid control of power. They can help eliminate loop flow in AC networks. High-voltage direct current (HVDC) lines and more recently HVDC "light" can completely avoid the problems of loop flow. Superconducting magnetic energy storage can be located strategically throughout the grid to damp out disturbances.[42]

Another class of technologies would increase the accuracy with which the limits of safe operation could be determined. These technologies take precise measurements of the system in real time. Real-time monitoring of the actual status of the power system would permit the introduction of sophisticated automatic controls to prevent blackouts. The Wide Area Measurement System was an early DOE-supported demonstration of the improvements in reliability management made possible by advanced measurements (see text box). Real-time monitoring of conductor temperatures would replace reliance on conservative, predetermined ratings for conductors, safely permitting increased flows over transmission lines.

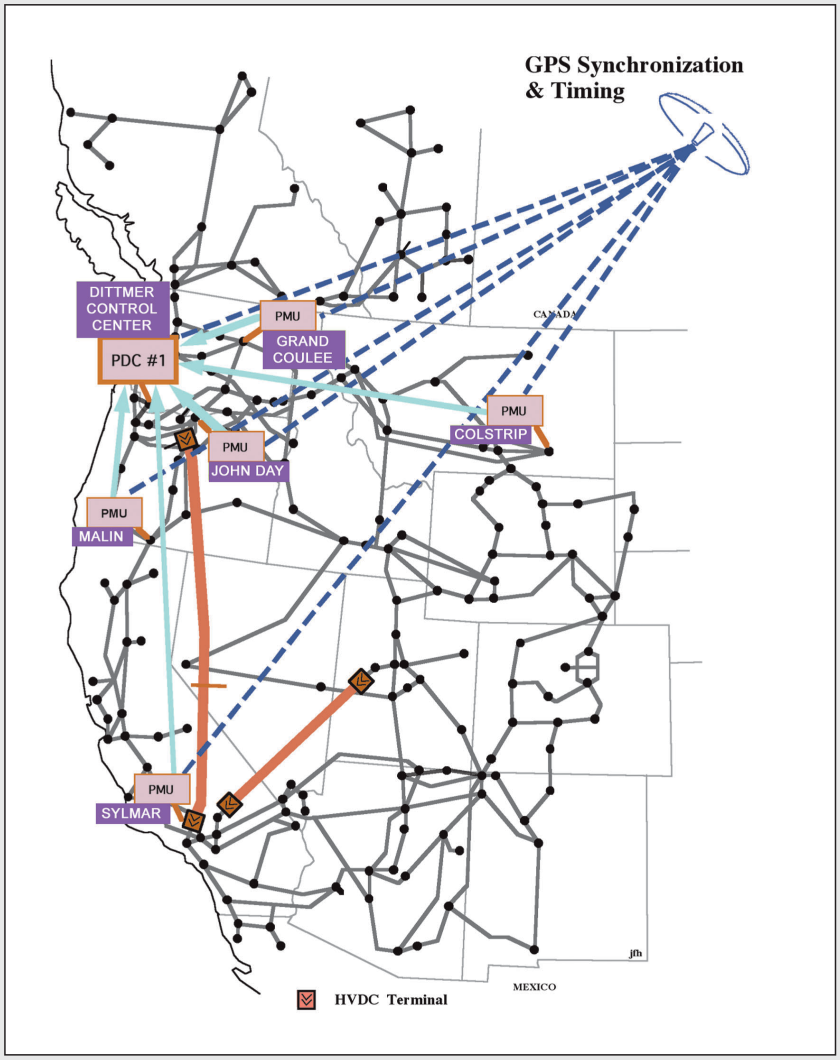
These hardware technologies can provide the muscle for improved transmission system capabilities, but software technologies are also needed to provide the intelligence to use these hardware technologies effectively. Advanced visualization techniques can dramatically enhance the ability of system operators to identify emerging grid problems in real time, assess options to address them, and take rapid corrective actions. New models and modeling techniques have improved our understanding of how the system behaves in response to region-wide transfers of electricity.

Encouraging the use of these new technologies is essential to make better use of existing transmission facilities and reduce the number of new facilities that are needed.



[42]It is also appropriate to consider non-transmission alternatives, such as controllable load and distributed generation, as technologies that enable greater control of electricity flows. See Section 4, "Relieving Transmission Bottlenecks Through Better Operations."

Wide Area Measurement Systems



Wide Area Measurement Systems (WAMS) technology is based on obtaining high-resolution power-system measurements (e.g., voltage) from sensors that are dispersed over wide areas of the grid, and synchronizing the data with timing signals from Global Positioning System (GPS) satellites. System operators currently retrieve archived data to analyze grid disturbances and improve system models; in the future, they will be able to use these data in real time to assess the health of the grid.

In 1995, DOE launched the WAMS project, in cooperation with Federal utilities and the private sector, to determine the information needs of the emerging power system and to develop technologies to meet these needs. A prototype WAMS network was installed, and software was developed to record, archive, and retrieve data.

The real-time information available from WAMS may allow operators to detect and mitigate a disturbance before it can spread and enable greater utilization of the grid by operating it closer to its limits while maintaining reliability. The capacity that is freed up is available to move larger amounts of power over the grid in response to competitive market transactions.

WAMS demonstrated its value following the massive Western system blackouts on August 10, 1996. Engineers began analyzing WAMS data within minutes of the blackout to reconstruct the sequence of events that led to it and to initiate corrective actions to restore service. DOE is working with Federal and private utilities to transfer this technology to system operators nationwide. Additional hardware and software enhancements using state-of-the-art technologies are needed to allow WAMS to realize its full potential.

Source: U.S. Department of Energy. http://www.eren.doe.gov/der/transmission

Continued development of these technologies is also expected to lead to a smart, switchable grid that can anticipate impending emergencies and automatically take preventive actions. Technologies such as these can protect the grid not only against traditional threats to reliability (such as storms and other natural events) but also against deliberate disruptions. (Transmission system security is discussed in more detail in the next subsection.)

Despite the obvious advantages of advanced transmission technologies, their development and deployment has been waning during the past 10 years. The uncertainties created by the anticipation of and the incomplete transition to a restructured electricity industry has led to a decline in traditional utility support for advanced technologies.

Before restructuring, funding for utility R&D was recovered in rates paid by all electricity consumers. In the vertically integrated industry of the past, collaborative, public-interest transmission-system R&D supported by all utilities (which did not compete with each other) was a logical complement to longer-range, higher-risk R&D, which was supported by the federal government.

Today, new institutions in the restructured industry, such as RTOs and ISOs, should be responsible for ensuring that adequate research and development is undertaken to support a reliable and efficient transmission system. However, these institutions have either not yet formed or have not been given an explicit charter to ensure adequate support for these activities. Once the transition to a restructured industry is complete, the private sector should once again be able to ensure adequate R&D investments. However, there is a critical need for the federal government to increase efforts to monitor and address emerging gaps in public-interest R&D for transmission technologies.

The areas appropriate for increased federal scrutiny and focus are defined by the technology requirements of reliable electric transmission systems that support regional competitive wholesale electricity markets. As noted in Section 3, there is a need for technologies to help manage the operations of large regional transmission systems reliably. As noted in Section 4, expanded efforts are also needed in the areas of improved real-time measurements, analysis of competitive market rules and their impacts on (and the opportunities they offer for enhancing) reliability, programs and technologies to enhance voluntary customer load reduction, and interconnection and integration of distributed generation.

Federal PMAs, such as BPA and WAPA, remain important, unique elements of the U.S. R&D infrastructure. TVA has been a leader in development and demonstration of advanced transmission technologies. These entities have a long tradition of multi-institutional R&D conducted in the public interest. Today, they are functioning, proven, and immediately available resources for joint public-private technology development efforts.

One of the gaps on the pathway to market is demonstration of advanced technologies in utility systems using utility procedures and independent evaluation of the performance of these technologies. One way to fill this gap would be to combine the expertise of DOE's national laboratories, TVA, and the PMAs to develop flexible field test facilities that can create realistic demonstrations of advanced technologies under a wide range of electrical conditions without jeopardizing normal operations. Overhead and underground transmission, composite conductors, high-temperature superconducting equipment, high-voltage power electronics, energy storage systems, and combinations of these technologies and other equipment would benefit from this type of test facility. Public-private partnerships should guide the evaluation of these technologies.

It is worth nothing that a crisis may be brewing upstream in power system engineering education as talented young engineers seek out careers in other, more lucrative professions. Some argue that the dearth of talented engineers is simply a reflection of a supply and demand system that has not valued power engineers sufficiently to attract young new recruits to the profession. The solution to the problem, these observers argue, is not to artificially increase the numbers of poorly paid engineers but instead to create a reward structure to attract the necessary talent. Regardless of the reason or the best solution, there is no question that there is at the moment an apparent shortage of qualified operating staff for the electricity power systems just at the time when many senior engineers—the collective engineering institutional memory of the industry—are about to retire.

RECOMMENDATIONS

- DOE will work with NARUC to develop guidance for state regulators and utilities on evaluating the risks of investment in innovative new technologies that advance public interests. These guidelines will help determine when a technology is a reasonable performance risk and how to weigh the costs and benefits of using a new versus an established technology.
- The PMAs and TVA should maintain their leadership of demonstration efforts to evaluate advanced transmission-related technologies that enhance reliability and lower costs to consumers.
- DOE will develop national transmission-technology testing facilities that encourage partnering with industry to demonstrate advanced technologies in controlled environments. Working with TVA, DOE will create an industry cost-shared transmission line testing center at DOE's Oak Ridge National Laboratory (with at least a 50 percent industry cost share).
- DOE will accelerate development and demonstration of its technologies, including high-temperature superconductivity, advanced conductors, energy storage, real-time system monitoring and control, voluntary load-reduction technologies and programs, and interconnection and integration of distributed energy resources.
- DOE will work with industry to develop innovative programs that fund transmission-related R&D, with special attention to technologies that are critical to addressing transmission bottlenecks.

5

Enhancing the Physical and Cyber Security of the Transmission System

Recent concern about national security issues has focused attention on the basic design of the interconnected transmission system and the reliability management philosophies that guide its operation. While DOE has included a limited discussion of transmission-related energy security issues in this subsection, this study is not intended as a comprehensive discussion of electricity infrastructure security issues.

Reliability has always taken into account the impacts of weather and random equipment failure. Extensions of existing practices, as well as new technologies and operating practices are now needed to protect the transmission system against deliberate, coordinated attacks. For example, increased reliance on distributed generation—electricity generation closer to the point of use (which would result in less reliance on the transmission system)—leads to a more robust electricity system.

As the U.S. moves forward with the modernization of its transmission systems, it is critical that infrastructure protection be built into these decisionmaking processes. Hardware and software technologies that are available in the market today can protect facilities, improve recovery and restoration speed, and reduce the effectiveness of deliberate attacks. The smart, switchable grid discussed in the previous subsection should be an important element in this portfolio; R&D on this concept must extend its capabilities to address multiple contingencies in the case of deliberate attack.

The Northeast Ice Storm of 1998—Lessons for Power System Recovery

No reasonable set of precautions can entirely prevent widespread disruptions of electrical services. However, when such disruptions do occur, their impact can be greatly reduced if advance preparations have been made.

Between January 5 and 10, 1998, a series of exceptionally severe ice storms struck large areas within New York, New England, Ontario, Quebec, and the Maritime Provinces. The worst freezing rains ever recorded in the region deposited ice up to three inches thick. Damage to transmission and distribution facilities was severe—more than 770 transmission towers collapsed.

The Northeast ice storm showed that the following types of resources should be part of advance preparation for emergencies:

- **Comprehensive procedures for emergency management;**
- **Stockpiles of reserve equipment for emergency management and repair of facilities; and**
- **Procedures to ensure that adequate numbers of trained personnel can be mobilized.**

Source: Northeast Power Coordinating Council. 1998. *January 1998 Ice Storm—Final Report.* http://www.npcc.org

It should be designed to prevent, detect, and mitigate threats to reliability.

Unlike operational failures of the grid, which can usually be corrected within several hours, attacks on the grid are likely to result in the type of physical damage to equipment that is experienced in severe storms. The costs of service disruption to individual customers and to society rise sharply the longer an outage lasts. Emergency preparedness can greatly mitigate the impact of widespread disruptions whether they are natural events or the result of malicious attack. Recent experiences with natural disasters may be used as a roadmap for advance planning to minimize disruptions.

There is great diversity of electricity system and equipment designs and parts. Our electricity systems were designed by hundreds of local utilities with little consideration for standardization. Discussions within the industry should identify key hardware and software items that link our transmission system and evaluate the costs and benefits associated with standardizing equipment, where possible, and maintaining a reserve supply of transmission equipment. Reserve equipment is shared among utilities today; now is the time to ensure that adequate reserves of equipment are also available in a restructured market tomorrow.

We have an unprecedented opportunity to address these issues. As RTOs begin the process of building the software and hardware needed to operate our regional transmission systems, energy security issues should be factored into decisions on how we can best protect the reliability of our transmission system.

Critical Infrastructure Protection

DOE works closely in partnership with industry to address critical infrastructure protection challenges. DOE has led assessments to help industry understand the vulnerability of its systems to cyber or physical disruptions and identify ways to mitigate these vulnerabilities. DOE also works with industry to provide security alerts, contain and divert attacks, plan a system that can respond effectively to energy-sector attacks, and identify ways to facilitate rapid restoration of the system.

http://www.energy.gov/

RECOMMENDATIONS

- DOE will work with industry to evaluate the feasibility of adopting modular designs and standards for substation and other transmission equipment to facilitate rapid replacement.
- DOE and the national laboratories will continue to develop cost-effective technologies that improve the security of, protect against, mitigate the impacts of, and improve the ability to recover from disruptive incidents within the energy infrastructure.
- DOE will continue to develop energy infrastructure assurance best practices through vulnerability and risk assessments.
- DOE will work with industry to evaluate the costs and benefits associated with maintaining a reserve supply of transmission equipment that is funded by transmission rates. This reserve would be a resource in case of major outages resulting from terrorism or natural disasters.
- DOE will continue to work with industry to promote education and awareness in the industry about critical transmission infrastructure issues.
- DOE will continue to work closely with industry and state and local officials on implementation plans that respond to attacks on our transmission infrastructure.
- DOE will continue to provide training in critical infrastructure protection matters and energy emergency operations to state government agencies and to private industry.
- DOE will study the Eastern and Western AC Interconnections to assess the costs and benefits, including impacts on national security, of a series of smaller interconnections that are electrically independent of one another with DC links between them.
- DOE will work with industry and the states to develop standardized security guidelines to help reduce the cost of facility protection and facilitate consequence management.